(12)

AD-A134 616

THE BDM CORPORATION

7915 JONES BRANCH DRIVE McLEAN, VIRGINIA 22102-3396 (703) 821-5000 TELEX: 901103 BDM MCLN

ASSESSMENT OF THE POTENTIAL OF LANGMUIR-BLODGETT FILMS FOR ROOM TEMPERATURE IR DETECTORS

September 30, 1983

12

THE BDM CORPORATION

7915 JONES BRANCH DRIVE · McLEAN, VIRGINIA 22102-3396 · (703) 821-5000 · TELEX: 901103 BDM MCLN

ASSESSMENT OF THE POTENTIAL OF LANGMUIR-BLODGETT FILMS FOR ROOM TEMPERATURE IR DETECTORS

September 30, 1983

BDM/W-83-617-TR

Sponsored by

Defense Advanced Research Projects Agency (DoD)
DARPA Order Number 4114
Under Contract Number MDA903-83-C-0053 issued by
Department of Army, Defense Supply Service-Washington
Washington, D.C. 20310

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A134 616	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Assessment of the Potential of Langmuir-Blodgett Films for Room Temperature IR Detectors		5. TYPE OF REPORT & PERIOD COVERED Technical Report 7 Jan 83 - 30 Sep 83
		6. PERFORMING ORG. REPORT NUMBER BDM/W-83-610-TR
7. AUTHOR(s) Dr. A. D. Schnitzler		8. CONTRACT OR GRANT NUMBER(s) MDA903-83-C-0053
9. PERFORMING ORGANIZATION NAME AND ADDRESS The BDM Corporation 7915 Jones Branch Drive McLean, Virginia 22102		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARPA Order Number 4114
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency 1400 Wilson Boulevard Arlington, Virginia 22209		12. REPORT DATE 30 September 1983
		13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Defense Supply Service - Washington Room 1D-245 - The Pentagon Washington, DC 20310		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Infrared Detectors; Surface Passivation; Langmuir-Blodgett Films; Photoconductors; Photodiodes; Mercury-Cadmium Telluride

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Langmuir-Blodgett films possess high dielectric breakdown voltages and induce low surface state densities on semiconductor surfaces. These properties are valuable for surface passivation in manufacture of infrared detectors. It was suggested that these properties might be exploited in the fabrication of mercury cadmium telluride IR detectors that could operate at room temperature. (Cont'd)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

However, examination of the temperature dependence of the fundamental thermal noise sources in LWIR detectors indicate that these are characteristic of bulk properties and even detectors made with high quality materials (high purity, high crystalline perfection) must be cooled to the vicinity of liquid nitrogen temperature to achieve background limited operation. Better passivation would reduce 1/f noise in some device configurations and reduce leakage current in junction devices permitting higher RA products at below liquid nitrogen temperatures for low background operation.

TABLE OF CONTENTS

CHAPTER I
EXECUTIVE SUMMARY

The objective of this study is to determine the validity of a suggestion that the properties of Langmuir-Blodgett films might be exploited in the fabrication of mercury-cadmium telluride (MCT) infrared detectors that could operate at room temperature. Such devices would have major Defense applications by eliminating the current need to cool small bandgap long wavelength IR detectors to liquid nitrogen temperatures.

The approach followed in this study was to review the characterization of the performance of infrared detectors in terms of the specific detectivity, identifying internal noise sources, and analyzing their temperature dependence to determine whether Langmuir-Blodgett films could reduce their magnitude.

The major IR detector devices are photoconductors and diode devices such as p/n junction, Schottky barrier, and MIS charge coupled devices. The internal noise sources can be classified as either bulk or surface sources. Langmuir-Blodgett films can only affect surface sources.

The results of the study show that the fundamental noise current source in photoconductive detectors is thermal generation-recombination of electron-hole pairs. This process in ideal n-type MCT material is limited by the Auger process. It is found that to reduce thermal GR noise to the level of background photon induced GR noise, PC detectors with response in the 8-12 micrometer band must be cooled to about 90°K. Present PC detectors achieve essentially BLIP performance at 77°K. Better passivation such as might be provided by LB films would provide only a marginal improvement--mostly by reducing 1/f noise.

The results of the study also show that the fundamental noise current sources in p/n junction detectors are minority carrier diffusion, Shockley-Read GR in the depletion region, and surface leakage. Above about 100°K to 60°K, depending on the quality of the MCT material, diffusion current is dominant. Down to about 50°K, GR current is dominant and

below about 50°K leakage current is dominant. To achieve BLIP performance with p/n junction detectors in the 8-10 micrometer spectral band, it is necessary to reduce the diffusion current by cooling to about 77°K. Thus, better passivation will not permit room temperature operation. However, better passivation would yield higher R_oA_d products and BLIP operation with longer cutoff wavelength detectors at temperatures below 77°K.

Since minority carrier diffusion and Shockley-Read GR currents are due to bulk properties common to all junction devices, cooling to the vicinity of liquid nitrogen temperatures will be required to achieve BLIP performance with any detectors in the 8-12 micrometer spectral band. Better passivation will reduce 1/f noise due to surface states and allow higher R_oA_d products for low background operation at less than 77°K.

CHAPTER II
INTRODUCTION

In a previous study,[1] the properties of Langmuir-Blodgett (LB) films and their potential applications were reviewed. In particular, it was observed that LB films possess high dielectric breakdown voltages and induce low surface state densities on semiconductor surfaces. These properties are valuable for surface passivation in the manufacture of infrared detectors. It has been suggested[2] that these properties might be exploited in the fabrication of mercury cadmium telluride (MCT) IR detectors that could operate at room temperature. Such devices would have major Defense applications by eliminating the need to cool small bandgap MCT IR detectors to liquid nitrogen temperatures. With this in mind, the objective of this study is to theoretically analyze the temperature dependence of the performance of MCT IR detectors and to determine if the use of LB films to passivate IR detectors could yield high performance IR detectors operating at room temperature.

The major MCT IR detection devices are photoconductors and diode devices such as p/n junction, Schottky barrier, and MIS charge coupled devices. The approach will be to analyze the noise limitations of these devices and their temperature dependencies to determine if ideal surface passivation could yield high performance room temperature operation. The results of the study show that the fundamental noise current source in photoconductive detectors is thermal generation--recombination of electron-hole pairs. This process in ideal n-type MCT material is limited by the Auger process. It is found that to reduce thermal GR noise to the level of background photon induced GR noise, PC detectors with response in the 8-12 micrometer band must be cooled to about 90°K. Present PC detectors achieve essentially BLIP performance at 77°K. Better passivation such as might be provided by LB films would provide only a marginal improvement--mostly by reducing 1/f noise.

The results of the study show that the fundamental noise current sources in p/n junction detectors are minority carrier diffusion, Shockley-Read GR in the depletion region, and surface leakage. Above about 100°K

to 60°K, depending on the quality of the MCT material, diffusion current is dominant. Down to about 50°K, GR current is dominant and below about 50°K leakage current is dominant. To achieve BLIP performance with p/n junction detectors in the 8-10 micrometer spectral band, it is necessary to reduce the diffusion current by cooling to about 77°K. Thus, better passivation will not permit room temperature operation. However, better passivation would yield higher R_oA_d products and BLIP operation with longer cutoff wavelength detectors at room temperatures below 77°K.

Since minority carrier diffusion and Shockley-Read GR currents are due to bulk properties common to all junction devices, cooling to the vicinity of liquid nitrogen temperatures will be required to achieve BLIP performance with any detectors in the 8-12 micrometer spectral band. Better passivation will reduce 1/f noise due to surface states and allow higher R_oA_d products for low background operation at less than 77°K.

CHAPTER III
CHARACTERIZATION OF THE PERFORMANCE OF INFRARED DETECTORS

The performance of IR detectors is commonly characterized by the specific detectivity, D_λ^*, for incident radiation at wavelength, λ. By definition D_λ^* is given by

$$D_\lambda^* = (A_d B_n)^{1/2}/NEP_d(\lambda) \qquad (1)$$

where A_d is the area of the detector, B_n is the noise bandwidth of the preamplifier and $NEP_d(\lambda)$ is the noise-equivalent-power at wavelength, λ. Thus, D_λ^* is the normalized detectivity of a detector and is equal to the signal-to-noise ratio when one watt of incident radiant power falls on a detector of area 1 cm^2 and the noise bandwidth is 1 Hz.

The values of $NEP_d(\lambda)$ and, hence, D_λ^* depend on the responsivity (e.g., in amperes/watt) of the IR detector to incident radiant power and the magnitudes of the various noise currents.

The photocurrent resulting from incident radiant power $P_d(\lambda_s)$ is given by

$$I_d = R_p(\lambda_s)P_d(\lambda_s) \qquad (2)$$

where $R_p(\lambda)$ is the primary responsivity (not including internal gain) of an IR detector within the pass band of the electrical circuit.

By the conventional definition of NEP, the noise current is given by

$$I_n = R_p(\lambda)NEP_d(\lambda) \qquad (3)$$

By substituting $NEP_d(\lambda)$ from Equation (3) into Equation (1), we obtain

$$D_\lambda^* = R_p(\lambda)(A_d B_n)^{1/2}/I_n \qquad (4)$$

By expressing the incident power in terms of the photon flux and the photocurrent in terms of the quantum efficiency, it can be shown that the responsivity is given by

$$R_p(\lambda) = \eta(\lambda) e \lambda / hc \qquad (5)$$

where $\eta(\lambda)$ is the quantum efficiency in excited charge carriers per photon at wavelength λ, e is the electron charge, h is Planck's constant and c is the speed of light. The responsivity at λ= 10 micrometers is given by $R_p = 8.05\eta$ amperes per watt.

If we substitute Equation (5) into Equation (4), we obtain

$$D^*_\lambda = e\, \eta(\lambda)\, \lambda\, (A_d B_n)^{1/2} / hcI_n \qquad (6)$$

The most fundamental source of noise current in IR detectors is that due to fluctuations in the photogeneration of charge carriers by the incident radiant power. The goal of IR detector developers is to reduce the magnitude of internal noise current sources below that due to the incident background radiant power. If all else fails, the internal noise sources can be reduced by cooling the detector. Hence, infrared detectors in most sensor systems are operated at cryogenic temperatures.

The noise current due to photogeneration, known as shot noise, is given by the well-known shot noise formula

$$I_n = (2\, eI_b B_n)^{1/2} \qquad (7)$$

where B_n is the noise band pass of the detector and its electrical circuit and I_b is the detector current generated by the background incident power. Thus, in analogy to Equation (2), the background current is given by

$$I_b = \int R_p(\lambda) P_{d\lambda} d\lambda \qquad (8)$$

where $P_{d\lambda}$ is the incident background spectral radiant power and the integral is over the spectral bandpass of the cold filter generally included in IR sensor systems.

If Equations (6-8) are combined, the D^*_λ of a background limited photodetector (BLIP) is given by

$$D^*_\lambda = \eta(\lambda_s)\lambda_s/hc(2\,\overline{\eta}\,N_d)^{1/2} \tag{9}$$

where N_d is the incident background photon flux density and η is the mean quantum efficiency in the spectral bandpass. $\overline{\eta}$ is given by

$$\overline{\eta} = (1/N_d A_d hc) \int \eta(\lambda) P_{d\lambda}(\lambda)\lambda d\lambda \tag{10}$$

To the approximation that the quantum efficiency is constant within the spectral band, we have

$$D^*_\lambda = (\lambda/hc)(\eta/2N_d)^{1/2} \tag{11}$$

The expression for D^*_λ, given by Equation (11), is not applicable to all BLIP infrared detectors. It is applicable to junction type IR photodetectors such as p/n photovoltaic and photodiode detectors, Schottky barrier detectors, and MIS detectors such as CCDs. In these devices, the photoexcited carriers are swept out before recombination can occur. However, in photoconductive detectors usually the conditions are such that recombination as well as photogeneration occurs. The additional effect of recombination in BLIP photoconductive detectors is to double the noise power and, hence, reduce the value of D^*_λ by a factor of square root of 2.

If the incident background photon flux is collected by the detector from the entire hemisphere in front of the detector, we have $N_d = N_b$, i.e., the incident flux density in photons/cm^2-sec is equal to the radiant flux emitted by a square cm of the hemisphere per second into 2π sterradians. By definition, D^{**}_λ is the specific detectivity of a detector exposed to the full hemisphere. Hence, by Equation (11) we have

$$D^{**}_{\lambda} = (\lambda/hc)(\eta/2N_b) \tag{12}$$

If the exposure is limited by an ideal cold stop, we have

$$N_d = N_b/4(f/no.)^2 \tag{13}$$

and if we substitute Equation (13) into Equation (12), we obtain

$$D^{*}_{\lambda} = 2(f/no.)D^{**}_{\lambda} \tag{14}$$

For the 8.5 - 11.5 micrometer spectral band, D^{**}_{λ} is approximately 6×10^{10} cm-Hz/w. This the value often quoted for D-star, but note D^{*}_{λ} depends on f/no. For example, if the f/no. is f/4, the value of the BLIP D-star is given by $D^{*}_{\lambda} = 4.8 \times 10^{11}$ cm-Hz/w.

In terms of the IR detector performance parameter, D^{*}_{λ}, the objectives of this study can be stated as (1) to determine the fundamental limits on the temperature dependence of internal noise current sources, and (2) to determine if the deposition of LB films on MCT detectors could reduce the internal noise current and allow BLIP operation at a higher operating temperature (room temperature).

CHAPTER IV
PHOTOCONDUCTIVE MCT DETECTORS

The responsivity (including gain) of a photoconductive (PC) IR detector within the passband of the electrical circuit is given by

$$R(\lambda) = (\tau / \tau_r) R_p(\lambda) \qquad (15)$$

where τ is the photoexcited carrier liftime, τ_r is the mean transit time of carriers between the detector electrodes, τ / τ_r is the PC gain, and $R_p(\lambda)$ is given by Equation (5). The mean transit time (τ_r) is given by $L/\mu E$ where L is the distance, μ is the carrier mobility, and E is the electric field. Thus, by Equation (15) the responsivity is proportional to E and, hence, the signal current of a PC detector given by

$$I_s = R(\lambda_s) P_d(\lambda_s) \qquad (16)$$

is also proportional to E.

The chief sources of internal noise current in PC detectors are Johnson noise given by

$$I_n = [4 \ \ TB_n/R_d]^{1/2} \qquad (17)$$

and thermal generation-recombinations (g-r) noise associated with the PC dark current is given by

$$I_n = (\tau / \tau_r)(4e^2 g_{th} A_d \delta B_n)^{1/2} \qquad (18)$$

where in Equation (17) R_d is the resistance of the detector, in Equation (18) g_{th} is the thermal generation rate of free carriers per unit volume of detector, and δ is the thickness of the PC detector. Note that the Johnson noise is independent of bias while the g-r noise current (being proportional to $1/\tau_r$ and, hence, E) is proportional to bias.

Since both the signal current and g-r noise current are proportional to bias while the Johnson noise is independent of bias, if we increase the bias the S/N ratio will increase until the g-r noise current is dominant. Thus, the thermal g-r noise current is the fundamental internal source of noise current in PC detectors.

Under optimum bias conditions, and at an operating temperature such that the thermal g-r noise current is the dominant internal noise source, the spectral detectivity is given by

$$D_\lambda^* = R_p/2e(g_{th}\,\delta)^{1/2} \tag{19}$$

Note that Equation (19) is a good approximation for detector thickness greater than approximately the reciprocal of the absorption coefficient, i.e., for

$$\delta > 1/\alpha \tag{20}$$

Generally, it has been assumed that $g_{th} = \overline{N}/\tau$ where $\overline{N}$ is the thermal equilibrium free carrier charge density. However, Long[3] pointed out that this expression for g_{th} only applies to extrinsic PC detectors. For intrinsic n-type MCT PC detectors, where the electron mobility is much greater than the hole mobility, the correct expression is

$$g_{th} = P/\tau \tag{21}$$

where P is the hole density.

If we substitute Equation (21) into Equation (19), we obtain

$$D_\lambda^* = (R_p/2e)(\tau/P\,\delta)^{1/2} \tag{22}$$

The minority carrier lifetime may be due to radiative recombination, the Auger process, bulk Shockley-Read recombination centers or surface Shockley-Read recombination centers. According to Kinch, et al.,[4] the minority carrier lifetime in high quality n-type MCT is limited by the Auger process for N_d greater than approximately $4 \times 10^{14} cm^{-3}$.

The Auger lifetime is given by

$$\tau_a = 2N_i^2 \tau_{ai}/N(N+P) \simeq 2N_i^2 \tau_{ai}/N^2 \quad (23)$$

where N_i is the intrinsic carrier density and τ_{ai} is the Auger lifetime of intrinsic material.

If we substitute the approximate expression for τ_a given by Equation (23) into Equation (22), we obtain

$$D_\lambda^* = (R_p/e)(\tau_{ai}/2N_D \delta)^{1/2} \quad (24)$$

According to Kinch, et al., at 77°K the intrinsic Auger lifetime in 0.1 ev MCT is about 10^{-3} sec. Thus, for $N_D = 4 \times 10^{14} cm^{-3}$, $\delta = 10$ micrometers and $R_p = 8.05\ \eta$ at $\lambda = 10$ micrometers we obtain $D_\lambda^* = 1.78 \times 10^{12}$ cmHz$^{1/2}$/w. Comparison of this value with the BLIP value with an f/4 optic (namely, $D_\lambda^* = 4.8 \times 10^{11}$), indicates that an Auger limited lifetime MCT PC detector with 10 micrometer cutoff wavelength can be operated above 77°K. However, the Auger lifetime is an exponetial function of 1/T and, hence, D_λ^* is a very rapidly decreasing function as T increases. Indeed, Kinch, et al., indicate the D_λ^* decreases by a factor of about 4 to about 4.5×10^{11} in raising the operating temperature from 77°K to 90°K.

Since the fundamental noise current source in n-type MCT is g-r noise due to the bulk Auger process and this limits the operating temperature to about 90°K, the use of Langmuir-Blodgett films to reduce surface states will not permit a higher operating temperature. In practical PC detectors, the presence of surface states may given rise to surface g-r noise current and 1/f current noise. Thus, the use of LB films for

surface passivation might reduce these non-fundamental noise sources and result in detectors operating at 77°K with D^*_λ values closer to the BLIP value.

CHAPTER V
PHOTODIODE MCT DETECTORS

The responsivity of IR photodiode detectors is simply the primary responsivity given by Equation (5) (i.e., IR photodiode detectors are not normally operated with sufficient reverse bias to produce avalanche gain) and, hence, the responsivity and photocurrent are independent of bias.

The power spectrum of the internal noise current of an IR photodiode is given by

$$I_n^2 = 4kT/R+2eI_o+I_{1/f} \tag{25}$$

where the first term is the Johnson noise due to junction resistance, the second term is the shot noise due to the dark current, I_o, and the third term is the 1/f noise current due to the interface states.

Since the photocurrent is independent of bias and both the shot noise and 1/f noise currents increase with bias, the S/N ratio decreases with increasing bias. Thus, from a S/N ratio consideration, the optimum operating condition for IR photodiode detectors is at zero bias. In this case, the noise current is given by

$$I_n^2 = (4kT/R_o)B_n \tag{26}$$

where R_o is the junction resistance at zero bias.

If we substitute Equation (26) into Equation (4), we obtain

$$D_\lambda^* = R(\lambda)(R_oA_d/kT)^{1/2}/2 \tag{27}$$

Note that D_λ^* is proportional to the square root of the R_oA_d product.

By combining Equations (5), (11), (14), and (27), it can be shown that the R_oA_d condition for the Johnson noise limited D_λ^* to equal the BLIP D_λ^* is given by

$$R_oA_d > 8(f/no.)^2kT/e^2\,\eta\; N_b \tag{28}$$

Note that the required value of R_oA_d is proportional to the detector operating temperature. For future reference, consider a PV detector operated at 77°K, with an f/4 optical aperture and viewing a background at 300°K in the 8.3 to 10-micrometer spectral band. At 300°K, the background radiant emittance into the hemisphere is equal to 2.5×10^{17} photons/cm^2-sec. If we substitute the above values of the parameters into condition (28) and assume $\eta = 0.7$, we obtain $R_oA_d > 32$ ohm-cm^2.

To determine the temperature dependence of the R_oA_d product, we note that the junction resistance at zero bias is given by

$$1/R_o = (dI_o/dV)_{V=0} \tag{29}$$

where the dark current I_o is given by

$$I_o = I_s[\exp(eV/kT)-1]+V/R_s \tag{30}$$

I_s is the diode saturation current, V is the applied voltage, and R_s is the shunt resistance.

By Equations (29) and (30), we obtain

$$1/R_o = eI_s/kT+1/R_s \tag{31}$$

The diode saturation current, the sum of two components, is given by

$$I_s = I_D + I_{GR} \tag{32}$$

where I_D is the diffusion current of minority carriers across the junction from within a diffusion length of either side of the junction and I_{GR} is the generation-recombination current due to Shockley-Read centers near mid-bandgap in the depletion region. These unwanted centers are caused by impurities and defects in the MCT material.

By substituting Equation (32) into Equation (31), we have

$$1/R_o = eI_D/kT + eI_{GR}/kT + 1/R_s \tag{33}$$

We can identify a resistance with the diffusion and GR currents. Thus, by Equation (33), we have

$$1/R_o = 1/R_D + 1/R_{GR} + 1/R_S \tag{34}$$

where

$$R_D = kT/eI_D \text{ and } R_{GR} = kT/eI_{GR} \tag{35}$$

The expressions for R_D and R_{GR} are derived by deriving the expressions for I_D and I_{GR} in terms of material parameters and substituting them into Equation (35).

For an n on p photodiode, where the p-type layer is of thickness considerably less than a diffusion length, the RA products are given by

$$R_D A_d = kTN_A \tau_n / e^2 N_i^2 b \text{ and } R_{GR} A_d = E_g \tau_o / e^2 W N_i \tag{36}$$

where N_A is the acceptor ion density on the p side, N_i is the intrinsic free carrier density, τ_n is the minority carrier (electron) lifetime on the p side, τ_o is the effective electron-hole lifetime in the depletion region due to Shockley-Read centers and W is the width of the depletion region.

The intrinsic carrier density, N_i, is given by

$$N_i = (N_C N_V)^{1/2} \exp(-E_g/2kT) \tag{37}$$

where N_C and N_V are the conduction and valence band densities of state, respectively. Thus, the temperature dependence of $R_d A_d$ and $R_{GR} A_d$ resides mostly in N_i.

By substituting Equation (37) into Equation (36), we obtain

$$R_D A_d = [kN_A \ \tau_n / e^2 (N_C N_V)^{1/2} b] T \exp(E_g/kT) \tag{38}$$

and

$$R_{GR} A_d = E_g \ \tau_o / e^2 W (N_C N_V)^{1/2} \exp\ (E_g 2kT) \tag{39}$$

By taking the logarithm of Equations (38) and (39), we obtain

$$\log R_D A_d = \log C_D + \log T + (E_g \log e/k)(1/T) \tag{40}$$

and

$$\log R_{GR} A_d = \log C_{GR} + (E_g \log e/2k)(1/T) \tag{41}$$

where C_D and C_{GR} are coefficients of the explicitly temperature dependent terms in Equations (38) and (39).

Note that log $R_D A_d$ and log $R_{GR} A_d$ are essentially proportional to 1/T but log $R_D A_d$ increases twice as fast. In practice, it is found that at room temperature $R_o A_d$ is determined by $R_D A_d$. As the operating temperature is lowered, this condition holds until T is in the vicinity of 100°K to 60°K depending on the quality (purity, crystalline perfection) of the MCT material. Below this transition temperature, $R_o A_d$ is determined by either $R_{GR} A_d$ or R_s, the shunt resistance depending on the quality of the diode passivation. For T less than about 50°K, nearly all experimental data reported indicate that $R_o A_d$ is determined by shunt resistance.

The best measured $R_o A_d$ products of 8-10 micrometer diodes at 77°K are somewhat less than 100 ohm-cm^2 (10-80 ohm-cm^3). Since $R_o A_d$ > 32 ohm-cm^2 is required to achieve BLIP performance, these best diodes are roughly BLIP. However, since $R_o A_d$ equals $R_D A_d$ above about 77°K and decreases exponentially with increasing temperature, there is no possibility of achieving BLIP performance at room temperature by the use of Langmuir-Blodgett films for better passivation. Better passivation potentially provided by LB films could result in higher $R_o A_d$ products at temperatures below 77°K where $R_o A_d$ is determined by shunt resistance.

With reference to Equation (36) for R_DA_d and $R_{GR}A_d$, it should be noted that heavier doping could increase both R_oA_d products since R_dA_d is proportional to N_A and $R_{GR}A_d$ is inversely proportional to W which is narrowed by heavier doping. However, it has been found that present doping of $N_A \simeq 10^{16}$ is about the limit before tunneling across the narrowed depletion region begins to occur.

CHAPTER VI
CONCLUSIONS

The performance of infrared detectors depends on their ability to convert an incident photon flux into a current without adding noise current to that resulting from the photon flux itself. Noise currents in IR detectors arise from thermal excitation of charge carriers by means of a number of fundamental processes.

In photoconductive detectors, the fundamental source of noise is thermal generation-recombination noise current. It has been shown that in high quality n-type mercury cadmium telluride g-r noise is determined by the Auger process. Examination of the temperature dependence of the g-r noise current and comparison with photon g-r noise current indicates that small bandgap IR detectors sensitive to the 8-12 micrometer spectral band can not be operated at room temperature regardless of the ideality of surface passivation.

A similar result was obtained for junction type detectors in particular p/n photodiodes, where the fundamental noise current is the Johnson noise of the junction resistance which in turn depends on diffusion current and the generation-recombination current due to defects in the depletion region of the junction.

Better passivation, such as might be provided by Langmuir-Blodgett films, would reduce 1/f noise and leakage current in junction devices.

REFERENCES

1. "Assessment of Langmuir-Blodgett Film Technology and Its Potential Applications", BDM/W-82-763-TR, December 31, 1982.

2. G. Roberts, personal communication, reported in Reference 1.

3. Donald Long, "Generation-Recombination Noise Limited Detectivities of Impurity and Intrinsic Photoconductive 8-14 μ Infrared Detectors", Infrared Phys., 7, 121 (1967).

4. M. A. Kinch, S. R. Borrello, and A. Simmons, "0.1 eV HgCdTe Photoconductive Detector Performance", Infrared Phys., 17, 127 (1977).